PATENT ABSTRACTS OF JAPAN

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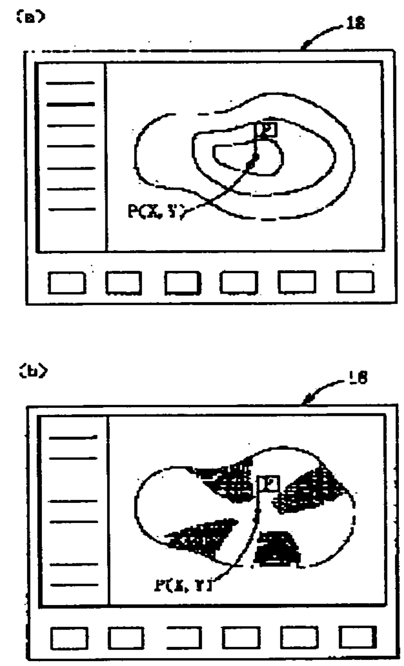
(54) MOIRE DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To find a range with precision between an object which is to be measured and the imaging lens of a observation optical system, for improved, in precision, image magnification and sensitivity correction for an accurate solid form information of the body, by flag-displaying a range-finding reference point of the object on a monitor for observing a moire fringe, related to a lattice projection type moire device provided with a fringe scan function.
SOLUTION: A moire fringe measurement is performed while a projection lattice is fringe-scanned, a 3-dimension data of a body which is to be measured is calculated from the measuring result, a range-finding reference point P (X, Y, Z) of the object is selected from the 3-dimension data, and the range-finding reference point P (X, Y, Z) is flag-displayed on a monitor 18 for observing a moire fringe measurement. Thus, with a pixel flag-displayed as an index, a range between the object and the imaging lens is measured.



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JAPANESE [JP,2000-046530,A]

CLAIMS DETAILED DESCRIPTION TECHNICAL FIELD PRIOR ART EFFECT OF THE INVENTION TECHNICAL PROBLEM MEANS DESCRIPTION OF DRAWINGS DRAWINGS

[Translation done.]

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CLAIMS

[Claim(s)]
[Claim 1] While having the projection optics and observation optical system which have the parallel optical axis of each other and making the image of a projection grid project on the measured body according to said projection optics Image formation of the deformation lattice image formed on said measured body of said observation optical system is carried out on the reference grid for observation. In the moire equipment which was constituted so that the Moire fringe which this produces might be observed, and was constituted so that said projection grid might be moved in the direction which intersects perpendicularly with the gridline of said both grids in the flat surface which intersects perpendicularly with said both opticals axis The three-dimension data of said measured body are computed from the Moire fringe observed while moving said projection grid. Moire equipment characterized by being constituted so that the ranging reference point on said measured body may be elected from this three-dimension data and this ranging reference point may be indicated by the flag on the monitor for Moire fringe observation.
[Claim 2] Moire equipment according to claim 1 with which said ranging reference point is characterized by being the top-most vertices of said measured body.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to moire equipment equipped with especially the fringe scanning function about the so-called grid projection type of moire equipment.
[0002]
[Description of the Prior Art] Conventionally, moire equipment is known as equipment for incorporating solid configuration information on the measured body easily for a short time. Although there are a thing of a grid exposure mold and a thing of a grid projection mold as moire equipment, since big reference grid of the latter like the former is unnecessary, it becomes what has the big measurement degree of freedom of the measured body.
[0003] The above-mentioned grid projection mold moire equipment carries out image formation of the deformation lattice image formed on the measured body of observation optical system on the reference grid for observation, and it is constituted so that the Moire fringe which this produces may be observed, while having the projection optics and observation optical system which have the parallel optical axis of each other and making the image of a projection grid project on the measured body according to projection optics. If it is made to perform the fringe scan for which a projection grid is moved in the direction which intersects perpendicularly with the gridline of both grids in the flat surface which intersects perpendicularly with both opticals axis in that case, since the concavo-convex judgment of the measured body will be attained by observing the directivity of change of the Moire fringe to migration of a projection grid, it becomes possible to acquire the solid configuration information on the measured body (Japanese-Patent-Application-No. No. 32214 [ten to] specification).
[0004]
[Problem(s) to be Solved by the Invention] By the way, by the Moire fringe formed on the measured body in the location near the taking lens of observation optical system, and the Moire fringe formed in a distant location, since the Moire fringe which appears on the monitor for Moire fringe observation is incorporated through observation optical system, even if it is the thing of the same gridline spacing, an actual depth dimension becomes a mutually different thing. Therefore, in order to acquire the exact solid configuration information on the measured body, it is necessary to perform amendment of an image scale factor and sensibility according to the location of the depth direction of each point on the measured body.
[0005] Since this image scale-factor amendment and correction by sensitiveness are relative location [each point / on the measured body / data / of the measured body computed from a Moire fringe although it is necessary to carry out according to distance absolutely / with the taking lens of observation optical system / three-dimension]-to the last data on the measured body, observation of a Moire fringe needs to measure the distance of the measured body and a taking lens independently.
[0006] Although this range measurement will be performed by the measurement using measurement or a measuring instrument by the handicraft which used the measure etc., since it is also a point used as the criteria of image scale-factor amendment and correction by sensitiveness, the point set as the object of the range measurement on the measured body in

that case is important when grasping correctly the location within the flat surface which intersects perpendicularly with that depth direction performs image scale-factor amendment and correction by sensitiveness with a sufficient precision.
[0007] This invention is made in view of such a situation , and aims at offer the moire equipment which can aim at improvement in precision of the image scale factor amendment which is needed in order to acquire the exact solid configuration information on the measured body , and correction by sensitiveness in the moire equipment of the grid projection mold equipped with the fringe scanning function .
[0008]
[Means for Solving the Problem] The moire equipment of this invention enables it to perform range measurement with the taking lens of observation optical system with a sufficient precision as the measured body by indicating the ranging reference point on the measured body by the flag on the monitor for Moire fringe observation.
[0009] Namely, while the moire equipment of this invention is equipped with the projection optics and observation optical system which have the parallel optical axis of each other and making the image of a projection grid project on the measured body according to said projection optics Image formation of the deformation lattice image formed on said measured body of said observation optical system is carried out on the reference grid for observation. In the moire equipment which was constituted so that the Moire fringe which this produces might be observed, and was constituted so that said projection grid might be moved in the direction which intersects perpendicularly with the gridline of said both grids in the flat surface which intersects perpendicularly with said both opticals axis The three-dimension data of said measured body are computed from the Moire fringe observed while moving said projection grid. The ranging reference point on said measured body is elected from this three-dimension data, and it is characterized by being constituted so that this ranging reference point may be indicated by the flag on the monitor for Moire fringe observation.
[0010] In addition, although the above "a ranging reference point" can adopt the point of the arbitration on the measured body, if the top-most vertices of the measured body are set up as a reference point, it can perform easily image scale-factor amendment after range measurement, and correction by sensitiveness.
[0011] Moreover, as for said ranging reference point, it is desirable that they are the top-most vertices of said measured body.
[0012]
[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention is explained using a drawing.
[0013] Drawing 1 is the perspective view showing the moire equipment (three-dimension image scanner) concerning 1 operation gestalt of this invention.
[0014] Like illustration this moire equipment 10 A measuring head 12 and the power-source device mechanical component 14, Come to have a control section 16 and a monitor 18, and the solid configuration information and encaustic (texture) information on the measured body 2 are incorporated in a measuring head 12. These solid configuration information and encaustic information are outputted to a control section 16 through the power-source device mechanical component 14, in a control section 16, synthetic processing of solid configuration information and the encaustic information is carried out, the three-dimension image of the measured body 2 is generated, and this is displayed on a monitor 18. The keyboard 20 and the mouse 22 are connected to the control section 16, and change actuation of the contents of a display, such as modification of the display include angle of the three-dimension image in a monitor 18, can be performed now to it by operating these.
[0015] Incorporation of the solid configuration information in a measuring head 12 is performed using grid projection mold moire topography. In drawing 1 , the lattice plane Pg shown according to a two-dot chain line ahead of a measuring head 12 is a virtual criteria lattice plane in grid projection mold moire topography.
[0016] Drawing 2 is the perspective view showing the appearance of a measuring head 12, and drawing 3 is the perspective view showing the internal structure of a measuring head 12.

[0017] As shown in these drawings, projection optics 26, the observation optical system 28, and the measured body illumination system 30 are established in casing 24, and this measuring head 12 has become.
[0018] Projection optics 26 comes to have the grid illumination system 38 which consists of the lamp 32 for projection, a heat ray cut-off filter 34, and a condensing lens 36, the projection grid 40, and the projection lens 42, and, on the other hand, the observation optical system 28 has come to have a taking lens 44, the reference grid 46 for observation, and the television optical system 54 that consists of the field lens 48, a clinch mirror 50, and CCD camera 52.
[0019] The projection lens 42 and the taking lens 44 are attached in the front face of casing 24 as each of those opticals axis Ax1 and Ax2 become parallel mutually.
[0020] The grid illumination system 38 is arranged so that the projection grid 40 may be irradiated from Hidari slanting back to an optical axis Ax1, and abbreviation image formation of the image of the lamp 32 for projection is carried out to the entrance pupil location of the projection lens 42. The condensing lens 36 has the magnitude which covers the projection grid 40 enough.
[0021] On the other hand, the field lens 48 and the clinch mirror 50 of the reference grid 46 for observation and the television optical system 54 are arranged on the optical axis Ax2, and CCD camera 52 is arranged on the optical axis which broke into the right angle again by the mirror 50 by return to the optical axis Ax2. The field lens 48 is arranged so that it may not leak and incidence of the flux of light which penetrated the reference grid 46 for observation may be carried out to CCD camera 52.
[0022] The projection grid 40 and the reference grid 46 for observation all have mutually the gridline prolonged in the vertical direction in the equal pitch, and are prepared in the same flat surface which intersects perpendicularly with opticals axis Ax1 and Ax2. And it is arranged by physical relationship the virtual criteria lattice plane Pg and conjugate so that image formation of the image of this projection grid 40 may be carried out to the virtual criteria lattice plane Pg (refer to drawing 1), it may be arranged by physical relationship the virtual criteria lattice plane Pg and conjugate and, as for the projection grid 40, image formation of the image of the virtual criteria lattice plane Pg may be carried out also for the reference grid 46 for observation to the reference grid 46 for observation on the other hand.
[0023] Drawing 4 is a top view explaining the function as grid projection mold moire equipment of a measuring head 12.
[0024] Like illustration, while making the image of the projection grid 40 project on the measured body 2 according to projection optics 26 in this measuring head 12, image formation of the deformation lattice image formed on the measured body 2 of the observation optical system 28 is carried out on the reference grid 46 for observation, and it is constituted so that the Moire fringe which this produces may be observed.
[0025] Two or more fields shown as a continuous line parallel to the virtual criteria lattice plane Pg and the virtual criteria lattice plane Pg which are shown with a dashed line in drawing 4 will form the moire side, and a Moire fringe will be formed along with the curve which each [these] moire side and the measured body 2 intersect. Although the continuous line shows the moire side only to the near side of the virtual criteria lattice plane Pg at drawing 4 , two or more moire sides are formed also in the back side of the virtual criteria lattice plane Pg. Therefore, a Moire fringe is formed, when it has been arranged so that the measured body 2 may straddle the virtual criteria lattice plane Pg forward and backward.
[0026] As shown in drawing 3 , the projection grid 40 is supported by the grid delivery device 56, and carries out both-way migration horizontally (namely, direction which intersects perpendicularly with the gridline of the projection grid 40) into the flat surface which intersects perpendicularly with an optical axis Ax1 according to the grid delivery device 56. This grid delivery device 56 consists of pulse stages equipped with the pulse motor, and carries out both-way vibration (fringe scan) of the projection grid 40 covering the die length for one phase. In addition, it replaces with a pulse stage and may be made to perform both-way vibration using a piezoelectric device etc.
[0027] Since the phase between the projection grid 40 and the reference grid 46 for observation

changes, a Moire fringe changes with migration of the projection grid 40 in connection with this. Then, the concavo-convex judgment of the measured body 2 is performed by sampling the image of this Moire fringe every 1/4 phase in a control section 16 (referring to drawing 1).

[0028] On the other hand, the reference grid 46 for observation is supported by the grid evacuation device 58, can be made to move horizontally into the flat surface which intersects perpendicularly with an optical axis Ax2 according to the grid evacuation device 58, and can take now alternatively the Moire fringe observation post located in the optical path of the observation optical system 28 by this, and the evacuation location from which it separated from the optical path. Migration of the reference grid 46 for observation is performed by taking the grid evacuation knob 60 which projects from the right lateral of casing 24 in the grid evacuation device 58 with hand control. When the reference grid 46 for observation moves to an evacuation location, the limit switch 62 which detects this is attached in the grid evacuation device 58.

[0029] Where the reference grid 46 for observation is set to a Moire fringe observation post, it is carried out, but the Moire fringe observation for incorporation of the solid configuration information on the measured body 2 will become possible [photoing the two-dimensional image of the measured body 2 with which the Moire fringe is not formed], if it is made to evacuate the reference grid 46 for observation to an evacuation location. Then, in a measuring head 12, encaustic information on the measured body 2 is incorporated by photography of this two-dimensional image.

[0030] As shown in drawing 3 , as the measured body illumination system 30 is located between the observation optical system 28 as projection optics 26, it is established. This measured body illumination system 30 consists of the lamp 64 for lighting, a heat ray cut-off filter 66, and a diffuser aperture 68 attached in the front face of casing 24, and carries out the diffusion exposure of the light from the lamp 64 for lighting to the front through the heat ray cut-off filter 66 and the diffuser aperture 68.

[0031] Although the lamp 64 for lighting is in an astigmatism LGT condition in the case of Moire fringe observation, it is turned on in the case of two-dimensional image photography. Moreover, it has become as [put / this lighting actuation is interlocked with and / the light / the lamp 32 for projection of the grid illumination system 38]. This lighting change is performed based on the detecting signal of a limit switch 62.

[0032] Thus, since the two-dimensional image of the measured body 2 will be photoed where the image of the projection grid 40 is formed if two-dimensional image photography is performed in the condition [having made the lamp 32 for projection freely turn on without making the lamp 64 for lighting turn on], the lighting change on the lamp 64 for lighting from the lamp 32 for projection is performed for avoiding this in the case of two-dimensional image photography. In addition, since the effect of the image of the projection grid 40 will become very small even if it made the lamp 32 for projection turn on freely if the lamp 64 for lighting is made to turn on, it is not necessarily required for lighting actuation of the lamp 64 for lighting to be interlocked with, and to make the lamp 32 for projection switch off.

[0033] Cooling fans 70 and 72 are attached in the left lateral and tooth back of casing 24, and the heat which the lamp 32 for projection and the lamp 64 for lighting emit by this is discharged to the exterior of casing 24. In that case, by the septa 74 and 76 formed in casing 24, the heat which both the lamps 32 and 64 emit is efficiently led to a cooling fan 70, further, another septum 78 is formed between CCD camera 52 and a septum 76, a heat insulation way is formed between both [these] the septa 76 and 78, and the air in a heat insulation way (heat) is led to a cooling fan 72. And it prevents certainly that the heat which both the lamps 32 and 64 emit gets across to CCD camera 52 by this, and CCD camera 52 is protected.

[0034] As shown in drawing 2 , the cold suction holes 80 and 82 are formed in the upper part part of both the lamps 32 and 64 in the top face of casing 24, and this raises the exhaust heat effectiveness by cooling fans 70 and 72.

[0035] Moreover, the electric power switch 84 and the energization display lamp 86 other than the grid evacuation knob 60 are formed in the right lateral of casing 24, and the electronic substrate 88 is formed in the inside side. Moreover, from the right lateral of casing 24, the power source and the code 90 for signals are prolonged, and the connector 92 for power sources, the

connector 94 for control signals, and the connector 96 for TV signals connect with the power-source device mechanical component 14 (refer to drawing 1) in the other end.
[0036] By the way, by the Moire fringe formed on the measured body 2 in the location near the taking lens 44 of the observation optical system 28, and the Moire fringe formed in a distant location, since the Moire fringe which appears on a monitor 18 is incorporated through the observation optical system 28 of a measuring head 12, even if it is the thing of the same gridline spacing, an actual depth dimension becomes a mutually different thing. Therefore, in order to acquire the exact solid configuration information on the measured body 2, it is necessary to amend an image scale factor according to the location of the depth direction of each point on the measured body 2.
[0037] For this reason, in this operation gestalt, while measuring the distance of the top-most vertices of the measured body 2, and a taking lens 44 in the case of observation of a Moire fringe, based on that ranging data, image scale-factor amendment and correction by sensitiveness of each point on the measured body 2 are performed. Since the point set as the ranging object on the measured body 2 in that case is also a point used as the criteria of image scale-factor amendment and correction by sensitiveness, it needs to grasp correctly the location within the flat surface (x, y flat surface) which intersects perpendicularly with the depth direction (the direction of z).
[0038] Then, in this operation gestalt, the top-most vertices of the measured body 2 are elected as a ranging reference point on the measured body 2, and it is constituted so that these top-most vertices may be indicated by the flag on a monitor 18.
[0039] Drawing 5 is drawing showing the procedure of the top-most-vertices election performed in the case of Moire fringe observation, range measurement, image scale-factor amendment, and correction by sensitiveness.
[0040] First, Moire fringe measurement performs top-most-vertices election (S1). That is, after performing striped analysis of a Moire fringe after capturing the image of a Moire fringe, performing a fringe scan, and performing height count with an internal-adjustment value, the three-dimension data (x y, z) of each point on the measured body 2 are computed, and top-most-vertices election is performed from this three-dimension data. Next, the elected top-most vertices are indicated by the flag on a monitor 18 (S2). If an operator checks this top-most-vertices location by which it was indicated by the flag and O.K. input is performed (S3), the distance of top-most vertices and a taking lens 44 will be measured automatically (S4). And after inputting the ranging numeric value automatically (S5), a height formula is calculated (S6) and image scale-factor amendment and correction by sensitiveness of each point on the measured body 2 are performed based on the result of an operation (S7).
[0041] Drawing 6 is drawing showing the concrete procedure of the top-most-vertices election by Moire fringe measurement of step S1.
[0042] First, the image of the measured body 2 with which 1 / 2pi [every] phase shifted is captured. If brightness I of the point is placed with I1, I2, I3, and I4 paying attention to one point P (x y) of each incorporation image in that case, it can express, as shown in this drawing (a).
[0043] It is phi=tan when it asks for the phase phi of this point from four brightness data with which these phases differ. - 1 {(I2-I4) /(I1-I3)}
It becomes.
[0044] When this phase phi is calculated about each point and that phase count result is made into a graph, it comes to be shown in this drawing (b). The maximum in this graph is 2pi, and serves as a curve which broke off to every 2pi.
[0045] When ANRAPPU processing which makes phase connection of this curve is performed to this intermittent curve, it comes to be shown in this drawing (c). Since height z (relative depth dimension of each point of the measured body 2) of each point of the image when setting the height per Moire fringe 1 stripes to delta (delta=2pi) is obtained by this, the top-most vertices of the measured body 2 can be found.
[0046] Namely, z1(x1, y1)-z2 (x2, y2) >=0 (or> 0)
It comes out, if it is, P (x1, y1, z1) will be chosen, and it is z1(x1, y1)-z2(x2, y2) <0 (or<=0).
It comes out, and if it is, comparison selection of choosing P (x2, y2, z2) will be performed over

the whole measurement field surface, and top-most vertices P (X, Y, Z) will be elected.
[0047] Since the frame memory and the pixel of CCD correspond by 1 to 1 at this time, the coordinate in a frame memory and the coordinate on a monitor become the congruous things.
[0048] Drawing 7 shows drawing which indicated the xy coordinate value P (X, Y) of the elected top-most vertices P (X, Y, Z) by the flag on the monitor 18. This drawing (a) shows the example which indicated by the flag to the image (for example, contour map) which displayed the Moire fringe analysis result, and this drawing (b) shows the example which indicated by the flag to a video through image. If drawing which indicated by the flag is switched and displayed on a monitor 18 in these two kinds of modes, visual inspection of top-most vertices P (X, Y, Z) having been elected appropriately can be ensured.
[0049] Drawing 8 is drawing for explaining how measuring automatically the distance of top-most vertices P (X, Y, Z) and a taking lens 44.
[0050] This automatic measure is performed using the technique of a general automatic focus.
[0051] First, on the occasion of an automatic measure, the reference grid 46 for observation is beforehand evacuated to an evacuation location.
[0052] And after checking that lens 52L of CCD camera 52 is in a home position, i.e., a criteria setup (1m) is made, the video signal of the pixel by which it was indicated by the flag is observed.
[0053] Next, lens 52L is moved in the direction of an optical axis, and peak detection is performed by the climbing-a-mountain method. And amount of displacement deltaL of the depth direction of the point by the side of the body corresponding to this movement magnitude epsilon is computed from the movement magnitude epsilon of lens 52L when this peak detection is performed. Distance L' (L'=L-deltaL) of the top-most vertices P of the measured body 2 (X, Y, Z) and a taking lens 44 (principal point H) is obtained from the distance L of the point by the side of a body in case lens 52L is in a home position, and the principal point (body side principal point) H of a taking lens 44 by computing the value which lengthened amount of displacement deltaL.
[0054] Peak detection by the above-mentioned climbing-a-mountain method is performed by the procedure shown in drawing 9 .
[0055] That is, as shown in this drawing (a), lens 52L of CCD camera 52 is moved in the direction of an optical axis, and as shown in this drawing (b), the image in each migration location is captured. In that case, as shown in this drawing (c), the output of the pixel corresponding to top-most vertices P (X, Y, Z) is plotted in a graph, and a lens location (namely, focusing point location) in case the output becomes max is determined as a peak detection location.
[0056] At this time, as are shown in drawing 10 (a), and the cross section of the direction of a x axis including the top-most vertices P in a peak detection location (X, Y, Z) and the direction of the y-axis is taken and it is shown in drawing 10 (b) and (c) If the output of each pixel of the direction of a x axis containing the pixel by which it was indicated by the flag, and the direction of the y-axis is plotted in a graph, it is verifiable that top-most vertices P (X, Y, Z) are peak value in the above-mentioned peak detection location.
[0057] In addition, the following relational expression is used for calculation of amount of displacement deltaL of the point by the side of the above-mentioned body.
[0058] That is, in drawing 8 , amount of displacement deltab of the image formation point formed with a taking lens 44 when the point by the side of a body does deltaL displacement of will be set to deltab=(f/(f-L))2deltaL, if the focal distance of a taking lens 44 is set to f. And the movement magnitude epsilon of lens 52L of CCD camera 52 accompanying this will be set to epsilon=(f'/(f'-L))2deltab if the focal distance of lens 52L is made into f'. Therefore, deltaL={(f'-L)(f-L) /f'f} 2epsilon is obtained from these 2 formula.
[0059] In this operation gestalt, although the case where distance of top-most vertices P (X, Y, Z) and a taking lens 44 was measured by the automatic measure was explained, it may be made to measure by handicraft using a measure etc. In this case, since the flag display of the top-most vertices P on a monitor 18 (X, Y, Z) is performed in the both sides of the image and video through image which displayed the Moire fringe analysis result, visual inspection of top-most vertices P (X, Y, Z) having been elected appropriately can be ensured.

[0060]
[Effect of the Invention] The moire equipment concerning this invention performs Moire fringe observation, carrying out the fringe scan of the projection grid. Since it is constituted so that the three-dimension data of the measured body may be computed from that result, the ranging reference point on the measured body may be elected from this three-dimension data and this ranging reference point may be indicated by the flag on the monitor for Moire fringe observation The point by which it was indicated by the flag can be made a mark, range measurement with the taking lens of observation optical system can be performed as the measured body, and the accuracy of measurement can be raised. And since the precision of image scale-factor amendment and correction by sensitiveness can be raised by this, the exact solid configuration information on the measured body can be acquired.
[0061] In this case, processing of the top-most vertices of the measured body then image scale-factor amendment, and correction by sensitiveness can be easy-ized for the above-mentioned reference point.

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PRIOR ART

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[0003] The above-mentioned grid projection mold moire equipment carries out image formation of the deformation lattice image formed on the measured body of observation optical system on the reference grid for observation, and it is constituted so that the Moire fringe which this produces may be observed, while having the projection optics and observation optical system which have the parallel optical axis of each other and making the image of a projection grid project on the measured body according to projection optics. If it is made to perform the fringe scan for which a projection grid is moved in the direction which intersects perpendicularly with the gridline of both grids in the flat surface which intersects perpendicularly with both opticals axis in that case, since the concavo-convex judgment of the measured body will be attained by observing the directivity of change of the Moire fringe to migration of a projection grid, it becomes possible to acquire the solid configuration information on the measured body (Japanese-Patent-Application-No. No. 32214 [ten to] specification).

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EFFECT OF THE INVENTION

[Effect of the Invention] The moire equipment concerning this invention performs Moire fringe observation, carrying out the fringe scan of the projection grid. Since it is constituted so that the three-dimension data of the measured body may be computed from that result, the ranging reference point on the measured body may be elected from this three-dimension data and this ranging reference point may be indicated by the flag on the monitor for Moire fringe observation The point by which it was indicated by the flag can be made a mark, range measurement with the taking lens of observation optical system can be performed as the measured body, and the accuracy of measurement can be raised. And since the precision of image scale-factor amendment and correction by sensitiveness can be raised by this, the exact solid configuration information on the measured body can be acquired.
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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] By the way, by the Moire fringe formed on the measured body in the location near the taking lens of observation optical system, and the Moire fringe formed in a distant location, since the Moire fringe which appears on the monitor for Moire fringe observation is incorporated through observation optical system, even if it is the thing of the same gridline spacing, an actual depth dimension becomes a mutually different thing. Therefore, in order to acquire the exact solid configuration information on the measured body, it is necessary to perform amendment of an image scale factor and sensibility according to the location of the depth direction of each point on the measured body.
[0005] Since this image scale-factor amendment and correction by sensitiveness are relative location [each point / on the measured body / data / of the measured body computed from a Moire fringe although it is necessary to carry out according to distance absolutely / with the taking lens of observation optical system / three-dimension]-to the last data on the measured body, observation of a Moire fringe needs to measure the distance of the measured body and a taking lens independently.
[0006] Although this range measurement will be performed by the measurement using measurement or a measuring instrument by the handicraft which used the measure etc., since it is also a point used as the criteria of image scale-factor amendment and correction by sensitiveness, the point set as the object of the range measurement on the measured body in that case is important when grasping correctly the location within the flat surface which intersects perpendicularly with that depth direction performs image scale-factor amendment and correction by sensitiveness with a sufficient precision.
[0007] This invention is made in view of such a situation , and aims at offer the moire equipment which can aim at improvement in precision of the image scale factor amendment which is needed in order to acquire the exact solid configuration information on the measured body , and correction by sensitiveness in the moire equipment of the grid projection mold equipped with the fringe scanning function .

[Translation done.]

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

MEANS

[Means for Solving the Problem] The moire equipment of this invention enables it to perform range measurement with the taking lens of observation optical system with a sufficient precision as the measured body by indicating the ranging reference point on the measured body by the flag on the monitor for Moire fringe observation.
[0009] Namely, while the moire equipment of this invention is equipped with the projection optics and observation optical system which have the parallel optical axis of each other and making the image of a projection grid project on the measured body according to said projection optics Image formation of the deformation lattice image formed on said measured body of said observation optical system is carried out on the reference grid for observation. In the moire equipment which was constituted so that the Moire fringe which this produces might be observed, and was constituted so that said projection grid might be moved in the direction which intersects perpendicularly with the gridline of said both grids in the flat surface which intersects perpendicularly with said both opticals axis The three-dimension data of said measured body are computed from the Moire fringe observed while moving said projection grid. The ranging reference point on said measured body is elected from this three-dimension data, and it is characterized by being constituted so that this ranging reference point may be indicated by the flag on the monitor for Moire fringe observation.
[0010] In addition, although the above "a ranging reference point" can adopt the point of the arbitration on the measured body, if the top-most vertices of the measured body are set up as a reference point, it can perform easily image scale-factor amendment after range measurement, and correction by sensitiveness.
[0011] Moreover, as for said ranging reference point, it is desirable that they are the top-most vertices of said measured body.
[0012]
[Embodiment of the Invention] Hereafter, the gestalt of operation of this invention is explained using a drawing.
[0013] Drawing 1 is the perspective view showing the moire equipment (three-dimension image scanner) concerning 1 operation gestalt of this invention.
[0014] Like illustration this moire equipment 10 A measuring head 12 and the power-source device mechanical component 14, Come to have a control section 16 and a monitor 18, and the solid configuration information and encaustic (texture) information on the measured body 2 are incorporated in a measuring head 12. These solid configuration information and encaustic information are outputted to a control section 16 through the power-source device mechanical component 14, in a control section 16, synthetic processing of solid configuration information and the encaustic information is carried out, the three-dimension image of the measured body 2 is generated, and this is displayed on a monitor 18. The keyboard 20 and the mouse 22 are connected to the control section 16, and change actuation of the contents of a display, such as modification of the display include angle of the three-dimension image in a monitor 18, can be performed now to it by operating these.
[0015] Incorporation of the solid configuration information in a measuring head 12 is performed using grid projection mold moire topography. In drawing 1, the lattice plane Pg shown according

to a two-dot chain line ahead of a measuring head 12 is a virtual criteria lattice plane in grid projection mold moire topography.
[0016] Drawing 2 is the perspective view showing the appearance of a measuring head 12, and drawing 3 is the perspective view showing the internal structure of a measuring head 12.
[0017] As shown in these drawings, projection optics 26, the observation optical system 28, and the measured body illumination system 30 are established in casing 24, and this measuring head 12 has become.
[0018] Projection optics 26 comes to have the grid illumination system 38 which consists of the lamp 32 for projection, a heat ray cut-off filter 34, and a condensing lens 36, the projection grid 40, and the projection lens 42, and, on the other hand, the observation optical system 28 has come to have a taking lens 44, the reference grid 46 for observation, and the television optical system 54 that consists of the field lens 48, a clinch mirror 50, and CCD camera 52.
[0019] The projection lens 42 and the taking lens 44 are attached in the front face of casing 24 as each of those opticals axis Ax1 and Ax2 become parallel mutually.
[0020] The grid illumination system 38 is arranged so that the projection grid 40 may be irradiated from the method of the diagonally rear to the left to an optical axis Ax1, and abbreviation image formation of the image of the lamp 32 for projection is carried out to the entrance pupil location of the projection lens 42. The condensing lens 36 has the magnitude which covers the projection grid 40 enough.
[0021] On the other hand, the field lens 48 and the clinch mirror 50 of the reference grid 46 for observation and the television optical system 54 are arranged on the optical axis Ax2, and CCD camera 52 is arranged on the optical axis which broke into the right angle again by the mirror 50 by return to the optical axis Ax2. The field lens 48 is arranged so that it may not leak and incidence of the flux of light which penetrated the reference grid 46 for observation may be carried out to CCD camera 52.
[0022] The projection grid 40 and the reference grid 46 for observation all have mutually the gridline prolonged in the vertical direction in the equal pitch, and are prepared in the same flat surface which intersects perpendicularly with opticals axis Ax1 and Ax2. And it is arranged by physical relationship the virtual criteria lattice plane Pg and conjugate so that image formation of the image of this projection grid 40 may be carried out to the virtual criteria lattice plane Pg (refer to drawing 1), it may be arranged by physical relationship the virtual criteria lattice plane Pg and conjugate and, as for the projection grid 40, image formation of the image of the virtual criteria lattice plane Pg may be carried out also for the reference grid 46 for observation to the reference grid 46 for observation on the other hand.
[0023] Drawing 4 is a top view explaining the function as grid projection mold moire equipment of a measuring head 12.
[0024] Like illustration, while making the image of the projection grid 40 project on the measured body 2 according to projection optics 26 in this measuring head 12, image formation of the deformation lattice image formed on the measured body 2 of the observation optical system 28 is carried out on the reference grid 46 for observation, and it is constituted so that the Moire fringe which this produces may be observed.
[0025] Two or more fields shown as a continuous line parallel to the virtual criteria lattice plane Pg and the virtual criteria lattice plane Pg which are shown with a dashed line in drawing 4 will form the moire side, and a Moire fringe will be formed along with the curve which each [these] moire side and the measured body 2 intersect. Although the continuous line shows the moire side only to the near side of the virtual criteria lattice plane Pg at drawing 4 , two or more moire sides are formed also in the back side of the virtual criteria lattice plane Pg. Therefore, a Moire fringe is formed, when it has been arranged so that the measured body 2 may straddle the virtual criteria lattice plane Pg forward and backward.
[0026] As shown in drawing 3 , the projection grid 40 is supported by the grid delivery device 56, and carries out both-way migration horizontally (namely, direction which intersects perpendicularly with the gridline of the projection grid 40) into the flat surface which intersects perpendicularly with an optical axis Ax1 according to the grid delivery device 56. This grid delivery device 56 consists of pulse stages equipped with the pulse motor, and carries out both-

way vibration (fringe scan) of the projection grid 40 covering the die length for one phase. In addition, it replaces with a pulse stage and may be made to perform both-way vibration using a piezoelectric device etc.
[0027] Since the phase between the projection grid 40 and the reference grid 46 for observation changes, a Moire fringe changes with migration of the projection grid 40 in connection with this. Then, the concavo-convex judgment of the measured body 2 is performed by sampling the image of this Moire fringe every 1/4 phase in a control section 16 (referring to drawing 1).
[0028] On the other hand, the reference grid 46 for observation is supported by the grid evacuation device 58, can be made to move horizontally into the flat surface which intersects perpendicularly with an optical axis Ax2 according to the grid evacuation device 58, and can take now alternatively the Moire fringe observation post located in the optical path of the observation optical system 28 by this, and the evacuation location from which it separated from the optical path. Migration of the reference grid 46 for observation is performed by taking the grid evacuation knob 60 which projects from the right lateral of casing 24 in the grid evacuation device 58 with hand control. When the reference grid 46 for observation moves to an evacuation location, the limit switch 62 which detects this is attached in the grid evacuation device 58.
[0029] Where the reference grid 46 for observation is set to a Moire fringe observation post, it is carried out, but the Moire fringe observation for incorporation of the solid configuration information on the measured body 2 will become possible [photoing the two-dimensional image of the measured body 2 with which the Moire fringe is not formed], if it is made to evacuate the reference grid 46 for observation to an evacuation location. Then, in a measuring head 12, encaustic information on the measured body 2 is incorporated by photography of this two-dimensional image.
[0030] As shown in drawing 3 , as the measured body illumination system 30 is located between the observation optical system 28 as projection optics 26, it is established. This measured body illumination system 30 consists of the lamp 64 for lighting, a heat ray cut-off filter 66, and a diffuser aperture 68 attached in the front face of casing 24, and carries out the diffusion exposure of the light from the lamp 64 for lighting to the front through the heat ray cut-off filter 66 and the diffuser aperture 68.
[0031] Although the lamp 64 for lighting is in an astigmatism LGT condition in the case of Moire fringe observation, it is turned on in the case of two-dimensional image photography. Moreover, it has become as [put / this lighting actuation is interlocked with and / the light / the lamp 32 for projection of the grid illumination system 38]. This lighting change is performed based on the detecting signal of a limit switch 62.
[0032] Thus, since the two-dimensional image of the measured body 2 will be photoed where the image of the projection grid 40 is formed if two-dimensional image photography is performed in the condition [having made the lamp 32 for projection freely turn on without making the lamp 64 for lighting turn on], the lighting change on the lamp 64 for lighting from the lamp 32 for projection is performed for avoiding this in the case of two-dimensional image photography. In addition, since the effect of the image of the projection grid 40 will become very small even if it made the lamp 32 for projection turn on freely if the lamp 64 for lighting is made to turn on, it is not necessarily required for lighting actuation of the lamp 64 for lighting to be interlocked with, and to make the lamp 32 for projection switch off.
[0033] Cooling fans 70 and 72 are attached in the left lateral and tooth back of casing 24, and the heat which the lamp 32 for projection and the lamp 64 for lighting emit by this is discharged to the exterior of casing 24. In that case, by the septa 74 and 76 formed in casing 24, the heat which both the lamps 32 and 64 emit is efficiently led to a cooling fan 70, further, another septum 78 is formed between CCD camera 52 and a septum 76, a heat insulation way is formed between both [these] the septa 76 and 78, and the air in a heat insulation way (heat) is led to a cooling fan 72. And it prevents certainly that the heat which both the lamps 32 and 64 emit gets across to CCD camera 52 by this, and CCD camera 52 is protected.
[0034] As shown in drawing 2 , the cold suction holes 80 and 82 are formed in the upper part part of both the lamps 32 and 64 in the top face of casing 24, and this raises the exhaust heat effectiveness by cooling fans 70 and 72.

[0035] Moreover, the electric power switch 84 and the energization display lamp 86 other than the grid evacuation knob 60 are formed in the right lateral of casing 24, and the electronic substrate 88 is formed in the inside side. Moreover, from the right lateral of casing 24, the power source and the code 90 for signals are prolonged, and the connector 92 for power sources, the connector 94 for control signals, and the connector 96 for TV signals connect with the power-source device mechanical component 14 (refer to drawing 1) in the other end.
[0036] By the way, by the Moire fringe formed on the measured body 2 in the location near the taking lens 44 of the observation optical system 28, and the Moire fringe formed in a distant location, since the Moire fringe which appears on a monitor 18 is incorporated through the observation optical system 28 of a measuring head 12, even if it is the thing of the same gridline spacing, an actual depth dimension becomes a mutually different thing. Therefore, in order to acquire the exact solid configuration information on the measured body 2, it is necessary to amend an image scale factor according to the location of the depth direction of each point on the measured body 2.
[0037] For this reason, in this operation gestalt, while measuring the distance of the top-most vertices of the measured body 2, and a taking lens 44 in the case of observation of a Moire fringe, based on that ranging data, image scale-factor amendment and correction by sensitiveness of each point on the measured body 2 are performed. Since the point set as the ranging object on the measured body 2 in that case is also a point used as the criteria of image scale-factor amendment and correction by sensitiveness, it needs to grasp correctly the location within the flat surface (x, y flat surface) which intersects perpendicularly with the depth direction (the direction of z).
[0038] Then, in this operation gestalt, the top-most vertices of the measured body 2 are elected as a ranging reference point on the measured body 2, and it is constituted so that these top-most vertices may be indicated by the flag on a monitor 18.
[0039] Drawing 5 is drawing showing the procedure of the top-most-vertices election performed in the case of Moire fringe observation, range measurement, image scale-factor amendment, and correction by sensitiveness.
[0040] First, Moire fringe measurement performs top-most-vertices election (S1). That is, after performing striped analysis of a Moire fringe after capturing the image of a Moire fringe, performing a fringe scan, and performing height count with an internal-adjustment value, the three-dimension data (x y, z) of each point on the measured body 2 are computed, and top-most-vertices election is performed from this three-dimension data. Next, the elected top-most vertices are indicated by the flag on a monitor 18 (S2). If an operator checks this top-most-vertices location by which it was indicated by the flag and O.K. input is performed (S3), the distance of top-most vertices and a taking lens 44 will be measured automatically (S4). And after inputting the ranging numeric value automatically (S5), a height formula is calculated (S6) and image scale-factor amendment and correction by sensitiveness of each point on the measured body 2 are performed based on the result of an operation (S7).
[0041] Drawing 6 is drawing showing the concrete procedure of the top-most-vertices election by Moire fringe measurement of step S1.
[0042] First, the image of the measured body 2 with which 1 / 2pi [every] phase shifted is captured. If brightness I of the point is placed with I1, I2, I3, and I4 paying attention to one point P (x y) of each incorporation image in that case, it can express, as shown in this drawing (a).
[0043] It is phi=tan when it asks for the phase phi of this point from four brightness data with which these phases differ. - 1 {(I2-I4) /(I1-I3)}
It becomes.
[0044] When this phase phi is calculated about each point and that phase count result is made into a graph, it comes to be shown in this drawing (b). The maximum in this graph is 2pi, and serves as a curve which broke off to every 2pi.
[0045] When ANRAPPU processing which makes phase connection of this curve is performed to this intermittent curve, it comes to be shown in this drawing (c). Since height z (relative depth dimension of each point of the measured body 2) of each point of the image when setting the height per Moire fringe 1 stripes to delta (delta=2pi) is obtained by this, the top-most vertices of

the measured body 2 can be found.
[0046] Namely, z1(x1, y1)-z2 (x2, y2) >=0 (or> 0)
It comes out, if it is, P (x1, y1, z1) will be chosen, and it is z1(x1, y1)-z2(x2, y2) <0 (or<=0). It comes out, and if it is, comparison selection of choosing P (x2, y2, z2) will be performed over the whole measurement field surface, and top-most vertices P (X, Y, Z) will be elected.
[0047] Since the frame memory and the pixel of CCD correspond by 1 to 1 at this time, the coordinate in a frame memory and the coordinate on a monitor become the congruous things.
[0048] Drawing 7 shows drawing which indicated the xy coordinate value P (X, Y) of the elected top-most vertices P (X, Y, Z) by the flag on the monitor 18. This drawing (a) shows the example which indicated by the flag to the image (for example, contour map) which displayed the Moire fringe analysis result, and this drawing (b) shows the example which indicated by the flag to a video through image. If drawing which indicated by the flag is switched and displayed on a monitor 18 in these two kinds of modes, visual inspection of top-most vertices P (X, Y, Z) having been elected appropriately can be ensured.
[0049] Drawing 8 is drawing for explaining how measuring automatically the distance of top-most vertices P (X, Y, Z) and a taking lens 44.
[0050] This automatic measure is performed using the technique of a general automatic focus.
[0051] First, on the occasion of an automatic measure, the reference grid 46 for observation is beforehand evacuated to an evacuation location.
[0052] And after checking that lens 52L of CCD camera 52 is in a home position, i.e., a criteria setup (1m) is made, the video signal of the pixel by which it was indicated by the flag is observed.
[0053] Next, lens 52L is moved in the direction of an optical axis, and peak detection is performed by the climbing-a-mountain method. And amount of displacement deltaL of the depth direction of the point by the side of the body corresponding to this movement magnitude epsilon is computed from the movement magnitude epsilon of lens 52L when this peak detection is performed. Distance L' (L'=L-deltaL) of the top-most vertices P of the measured body 2 (X, Y, Z) and a taking lens 44 (principal point H) is obtained from the distance L of the point by the side of a body in case lens 52L is in a home position, and the principal point (body side principal point) H of a taking lens 44 by computing the value which lengthened amount of displacement deltaL.
[0054] Peak detection by the above-mentioned climbing-a-mountain method is performed by the procedure shown in drawing 9 .
[0055] That is, as shown in this drawing (a), lens 52L of CCD camera 52 is moved in the direction of an optical axis, and as shown in this drawing (b), the image in each migration location is captured. In that case, as shown in this drawing (c), the output of the pixel corresponding to top-most vertices P (X, Y, Z) is plotted in a graph, and a lens location (namely, focusing point location) in case the output becomes max is determined as a peak detection location.
[0056] At this time, as are shown in drawing 10 (a), and the cross section of the direction of a x axis including the top-most vertices P in a peak detection location (X, Y, Z) and the direction of the y-axis is taken and it is shown in drawing 10 (b) and (c) If the output of each pixel of the direction of a x axis containing the pixel by which it was indicated by the flag, and the direction of the y-axis is plotted in a graph, it is verifiable that top-most vertices P (X, Y, Z) are peak value in the above-mentioned peak detection location.
[0057] In addition, the following relational expression is used for calculation of amount of displacement deltaL of the point by the side of the above-mentioned body.
[0058] That is, in drawing 8 , amount of displacement deltab of the image formation point formed with a taking lens 44 when the point by the side of a body does deltaL displacement of will be set to deltab=(f/(f-L))2deltaL, if the focal distance of a taking lens 44 is set to f. And the movement magnitude epsilon of lens 52L of CCD camera 52 accompanying this will be set to epsilon=(f'/(f'-L))2deltab if the focal distance of lens 52L is made into f'. Therefore, deltaL={(f'-L)(f-L) /f'f} 2epsilon is obtained from these 2 formula.
[0059] In this operation gestalt, although the case where distance of top-most vertices P (X, Y, Z) and a taking lens 44 was measured by the automatic measure was explained, it may be made

to measure by handicraft using a measure etc. In this case, since the flag display of the top-most vertices P on a monitor 18 (X, Y, Z) is performed in the both sides of the image and video through image which displayed the Moire fringe analysis result, visual inspection of top-most vertices P (X, Y, Z) having been elected appropriately can be ensured.

[Translation done.]

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3.In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The perspective view showing the whole moire equipment configuration concerning 1 operation gestalt of this invention
[Drawing 2] The perspective view showing the appearance of the measuring head of the moire equipment shown in drawing 1
[Drawing 3] The perspective view showing the internal structure of the measuring head shown in drawing 1
[Drawing 4] The top view explaining the function of the measuring head shown in drawing 1
[Drawing 5] The flow chart which shows the procedure of the top-most-vertices election performed in the case of the Moire fringe observation by the moire equipment shown in drawing 1, range measurement, image scale-factor amendment, and correction by sensitiveness
[Drawing 6] The schematic diagram for explaining the concrete procedure of the top-most-vertices election by Moire fringe measurement
[Drawing 7] The schematic diagram showing the condition of having indicated the elected top-most vertices by the flag on the monitor
[Drawing 8] The schematic diagram for explaining how measuring automatically distance with the taking lens of observation optical system as top-most vertices
[Drawing 9] The schematic diagram showing the procedure of the peak detection by the climbing-a-mountain method
[Drawing 10] The schematic diagram showing the verification approach of a peak detection location
[Description of Notations]
2 Measured Body
10 Three-Dimension Image Scanner (Moire Equipment)
12 Measuring Head
14 Power-Source Device Mechanical Component
16 Control Section
18 Monitor
24 Casing
26 Projection Optics
28 Observation Optical System
30 Measured Body Illumination System
32 Lamp for Projection
36 Condensing Lens
38 Grid Illumination System
40 Projection Grid
42 Projection Lens
44 Taking Lens
46 Reference Grid for Observation
48 Field Lens
50 Clinch Mirror

52 CCD Camera
52L Lens
54 Television Optical System
56 Grid Delivery Device
58 Grid Evacuation Device
62 Limit Switch
Ax1, Ax2 Optical axis
Pg Virtual criteria lattice plane
P (X, Y, Z) Top-most vertices (ranging reference point)

[Translation done.]

②

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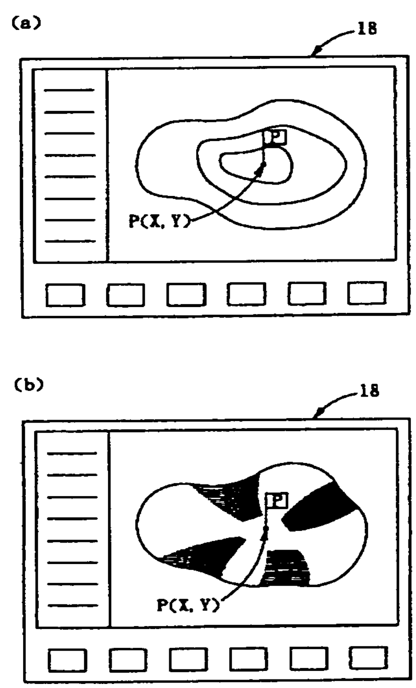
最終頁に続く

(54)【発明の名称】　モアレ装置

(57)【要約】
【目的】　フリンジスキャン機能を備えた格子投影型のモアレ装置において、被測定体上における測距基準点をモアレ縞観測用のモニタ上にフラグ表示することで、被測定体と観測光学系の撮影レンズとの距離測定を精度良く行い、被測定体の正確な立体形状情報を得るための像倍率および感度の補正の精度向上を図る。
【構成】　投影格子をフリンジスキャンさせながらモアレ縞測定を行い、その測定結果から被測定体の３次元データを算出し、この３次元データから被測定体上における測距基準点Ｐ（Ｘ，Ｙ，Ｚ）を選出し、この測距基準点Ｐ（Ｘ，Ｙ，Ｚ）をモアレ縞観測用のモニタ１８上にフラグ表示する構成とする。これによりフラグ表示されたピクセルを目印にして被測定体と撮影レンズとの距離測定を行えるようにする。



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【特許請求の範囲】

【請求項１】　互いに平行な光軸を有する投影光学系および観測光学系を備え、前記投影光学系により投影格子の像を被測定体上に投影させるとともに、前記観測光学系により前記被測定体上に形成された変形格子像を観測用基準格子上に結像させ、これにより生じるモアレ縞を観測するように構成され、かつ前記投影格子を前記両光軸と直交する平面内で前記両格子の格子線と直交する方向に移動させるように構成されたモアレ装置において、前記投影格子を移動させながら観測したモアレ縞から前記被測定体の３次元データを算出し、この３次元データから前記被測定体上における測距基準点を選出し、この測距基準点をモアレ縞観測用のモニタ上にフラグ表示するように構成されていることを特徴とするモアレ装置。

【請求項２】　前記測距基準点が、前記被測定体の頂点であることを特徴とする請求項１記載のモアレ装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、いわゆる格子投影型のモアレ装置に関するものであり、特にフリンジスキャン機能を備えたモアレ装置に関するものである。

【０００２】

【従来の技術】従来より、被測定体の立体形状情報の取り込みを短時間で容易に行うための装置としてモアレ装置が知られている。モアレ装置としては格子照射型のものと格子投影型のものとがあるが、後者は前者のような大きな基準格子が不要なため被測定体の測定自由度が大きなものとなる。

【０００３】上記格子投影型モアレ装置は、互いに平行な光軸を有する投影光学系および観測光学系を備えており、投影光学系により投影格子の像を被測定体上に投影させるとともに、観測光学系により被測定体上に形成された変形格子像を観測用基準格子上に結像させ、これにより生じるモアレ縞を観測するように構成されている。その際、投影格子を両光軸と直交する平面内で両格子の格子線と直交する方向に移動させるフリンジスキャンを行うようにすれば、投影格子の移動に対するモアレ縞の変化の方向性を観測することにより被測定体の凹凸判定が可能となるので、被測定体の立体形状情報を得ることが可能となる（特願平１０－３２２１４号明細書）。

【０００４】

【発明が解決しようとする課題】ところで、モアレ縞観測用のモニタ上に現れるモアレ縞は観測光学系を介して取り込まれるので、被測定体上において観測光学系の撮影レンズに近い位置で形成されるモアレ縞と遠い位置で形成されるモアレ縞とでは、同じ格子線間隔のものであっても実際の奥行き寸法は互いに異なったものとなる。したがって、被測定体の正確な立体形状情報を得るためには、被測定体上の各点の奥行き方向の位置に応じて像倍率および感度の補正を行う必要がある。

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【０００５】この像倍率補正および感度補正は被測定体上の各点と観測光学系の撮影レンズとの絶対距離に応じて行う必要があるが、モアレ縞から算出される被測定体の３次元データはあくまでも被測定体上における相対的な位置データであるので、モアレ縞の観測とは別に被測定体と撮影レンズとの距離を測定しておく必要がある。

【０００６】この距離測定は、メジャー等を用いた手作業による測定あるいは測定器具等を用いた測定により行われることとなるが、その際、被測定体上における距離測定の対象となる点は、像倍率補正および感度補正の基準となる点でもあるので、その奥行き方向と直交する平面内における位置を正確に把握しておくことが像倍率補正および感度補正を精度良く行う上で重要である。

【０００７】本発明は、このような事情に鑑みてなされたものであり、フリンジスキャン機能を備えた格子投影型のモアレ装置において、被測定体の正確な立体形状情報を得るために必要となる像倍率補正および感度補正の精度向上を図ることができるモアレ装置を提供することを目的とするものである。

【０００８】

【課題を解決するための手段】本発明のモアレ装置は、被測定体上における測距基準点をモアレ縞観測用のモニタ上にフラグ表示することにより、被測定体と観測光学系の撮影レンズとの距離測定を精度良く行えるようにしたものである。

【０００９】すなわち、本発明のモアレ装置は、互いに平行な光軸を有する投影光学系および観測光学系を備え、前記投影光学系により投影格子の像を被測定体上に投影させるとともに、前記観測光学系により前記被測定体上に形成された変形格子像を観測用基準格子上に結像させ、これにより生じるモアレ縞を観測するように構成され、かつ前記投影格子を前記両光軸と直交する平面内で前記両格子の格子線と直交する方向に移動させるように構成されたモアレ装置において、前記投影格子を移動させながら観測したモアレ縞から前記被測定体の３次元データを算出し、この３次元データから前記被測定体上における測距基準点を選出し、この測距基準点をモアレ縞観測用のモニタ上にフラグ表示するように構成されていることを特徴とするものである。

【００１０】なお、上記「測距基準点」は、被測定体上の任意の点を採用することが可能であるが、被測定体の頂点を基準点として設定すれば、距離測定後の像倍率補正および感度補正を容易に行うことができる。

【００１１】また、前記測距基準点は、前記被測定体の頂点であることが好ましい。

【００１２】

【発明の実施の形態】以下、図面を用いて、本発明の実施の形態について説明する。

【００１３】図１は、本発明の一実施形態に係るモアレ装置（３次元イメージスキャナ）を示す斜視図である。

【００１４】図示のように、このモアレ装置１０は、測定ヘッド１２と、電源機器駆動部１４と、制御部１６と、モニタ１８とを備えてなり、測定ヘッド１２において被測定体２の立体形状情報および模様（テクスチャ）情報を取り込み、これら立体形状情報および模様情報を、電源機器駆動部１４を介して制御部１６へ出力し、制御部１６において立体形状情報と模様情報とを合成処理して被測定体２の３次元イメージを生成し、これをモニタ１８に表示するようになっている。制御部１６には、キーボード２０およびマウス２２が接続されており、これらを操作することにより、モニタ１８における３次元イメージの表示角度の変更等その表示内容の切換え操作を行うことができるようになっている。

【００１５】測定ヘッド１２における立体形状情報の取り込みは、格子投影型モアレトポグラフィを利用して行うようになっている。図１において、測定ヘッド１２の前方に２点鎖線で示す格子面Ｐｇが、格子投影型モアレトポグラフィにおける仮想基準格子面である。

【００１６】図２は、測定ヘッド１２の外観を示す斜視図であり、図３は、測定ヘッド１２の内部構造を示す斜視図である。

【００１７】これらの図に示すように、この測定ヘッド１２は、ケーシング２４内に、投影光学系２６、観測光学系２８および被測定体照明系３０が設けられてなっている。

【００１８】投影光学系２６は、投影用ランプ３２、熱線カットフィルタ３４およびコンデンサレンズ３６からなる格子照明系３８と、投影格子４０と、投影レンズ４２とを備えてなり、一方、観測光学系２８は、撮影レンズ４４と、観測用基準格子４６と、フィールドレンズ４８、折り返しミラー５０およびＣＣＤカメラ５２からなるテレビ光学系５４とを備えてなっている。

【００１９】投影レンズ４２および撮影レンズ４４は、ケーシング２４の前面に、その各光軸Ａｘ１およびＡｘ２が互いに平行になるようにして取り付けられている。

【００２０】格子照明系３８は、光軸Ａｘ１に対して左斜め後方から投影格子４０を照射するように配置されており、その投影用ランプ３２の像は、投影レンズ４２の入射瞳位置に略結像されるようになっている。コンデンサレンズ３６は、投影格子４０を十分カバーする大きさを有している。

【００２１】一方、観測用基準格子４６ならびにテレビ光学系５４のフィールドレンズ４８および折り返しミラー５０は、光軸Ａｘ２上に配置されており、ＣＣＤカメラ５２は、光軸Ａｘ２に対して折り返しミラー５０により直角に折れ返された光軸上に配置されている。フィールドレンズ４８は、観測用基準格子４６を透過した光束をもれなくＣＣＤカメラ５２に入射させるように配置されている。

【００２２】投影格子４０および観測用基準格子４６は、いずれも互いに等しいピッチで上下方向に延びる格子線を有しており、光軸Ａｘ１およびＡｘ２と直交する同一平面内に設けられている。そして、投影格子４０は、該投影格子４０の像が仮想基準格子面Ｐｇ（図１参照）に結像されるよう、仮想基準格子面Ｐｇと共役の位置関係で配置されており、一方、観測用基準格子４６も、仮想基準格子面Ｐｇの像が観測用基準格子４６に結像されるよう、仮想基準格子面Ｐｇと共役の位置関係で配置されている。

【００２３】図４は、測定ヘッド１２の格子投影型モアレ装置としての機能を説明する平面図である。

【００２４】図示のように、この測定ヘッド１２においては、投影光学系２６により投影格子４０の像を被測定体２上に投影させるとともに、観測光学系２８により被測定体２上に形成された変形格子像を観測用基準格子４６上に結像させ、これにより生じるモアレ縞を観測するように構成されている。

【００２５】図４において１点鎖線で示す仮想基準格子面Ｐｇおよび仮想基準格子面Ｐｇと平行な実線で示す複数の面がモアレ面を形成しており、これら各モアレ面と被測定体２が交差する曲線に沿ってモアレ縞が形成されることとなる。図４には、仮想基準格子面Ｐｇの手前側にのみ実線でモアレ面を示しているが、仮想基準格子面Ｐｇの奥側にも複数のモアレ面が形成される。したがって、被測定体２が仮想基準格子面Ｐｇを前後にまたがるように配置された場合においてもモアレ縞は形成される。

【００２６】図３に示すように、投影格子４０は、格子送り機構５６に支持されており、格子送り機構５６により光軸Ａｘ１と直交する平面内において水平方向（すなわち投影格子４０の格子線と直交する方向）に往復移動せしめられるようになっている。この格子送り機構５６は、パルスモータを備えたパルスステージで構成されており、投影格子４０を１位相分の長さにわたって往復振動（フリンジスキャン）させるようになっている。なお、パルスステージに代えて圧電素子等を用いて往復振動を行うようにしてもよい。

【００２７】投影格子４０の移動により、投影格子４０と観測用基準格子４６との間の位相が変化するので、これに伴ってモアレ縞が変化する。そこで、このモアレ縞の像を制御部１６（図１参照）において１／４位相毎にサンプリングすることにより、被測定体２の凹凸判定を行うようになっている。

【００２８】一方、観測用基準格子４６は、格子退避機構５８に支持されており、格子退避機構５８により光軸Ａｘ２と直交する平面内において水平方向に移動せしめられ、これにより観測光学系２８の光路内に位置するモアレ縞観測位置と光路から外れた退避位置とを選択的に採り得るようになっている。観測用基準格子４６の移動は、格子退避機構５８においてケーシング２４の右側面

から突出する格子退避ノブ６０を、手動により出し入れすることにより行われるようになっている。格子退避機構５８には、観測用基準格子４６が退避位置まで移動したとき、これを検出するリミットスイッチ６２が取り付けられている。

【００２９】被測定体２の立体形状情報の取り込みのためのモアレ縞観測は、観測用基準格子４６をモアレ縞観測位置にセットした状態で行われるが、観測用基準格子４６を退避位置へ退避させるようにすれば、モアレ縞が形成されていない被測定体２の２次元画像の撮影を行うことが可能となる。そこで、測定ヘッド１２においては、この２次元画像の撮影により被測定体２の模様情報の取り込みを行うようになっている。

【００３０】図３に示すように、被測定体照明系３０は、投影光学系２６と観測光学系２８との間に位置するようにして設けられている。この被測定体照明系３０は、照明用ランプ６４と、熱線カットフィルタ６６と、ケーシング２４の前面に取り付けられたディフューザ窓６８とからなり、照明用ランプ６４からの光を、熱線カットフィルタ６６およびディフューザ窓６８を介して前方へ拡散照射するようになっている。

【００３１】照明用ランプ６４は、モアレ縞観測の際には非点灯状態にあるが、２次元画像撮影の際には点灯するようになっている。また、この点灯動作と連動して格子照明系３８の投影用ランプ３２が消灯するようなっている。この点灯切換えは、リミットスイッチ６２の検出信号に基づいて行われるようになっている。

【００３２】このように２次元画像撮影の際、投影用ランプ３２から照明用ランプ６４への点灯切換えが行われるのは、照明用ランプ６４を点灯させずに投影用ランプ３２を点灯させたままの状態で２次元画像撮影を行うと、投影格子４０の像が形成された状態で被測定体２の２次元画像を撮影することとなってしまうので、これを回避するためである。なお、照明用ランプ６４を点灯させれば、投影用ランプ３２を点灯させたままであっても投影格子４０の像の影響は非常に小さいものとなるので、照明用ランプ６４の点灯動作と連動して投影用ランプ３２を消灯させることは必ずしも必要ではない。

【００３３】ケーシング２４の左側面および背面には、冷却ファン７０および７２が取り付けられており、これにより投影用ランプ３２および照明用ランプ６４が発する熱をケーシング２４の外部へ排出するようになっている。その際、ケーシング２４内に形成された隔壁７４および７６により、両ランプ３２および６４が発する熱を冷却ファン７０へ効率よく導くようになっており、さらに、ＣＣＤカメラ５２と隔壁７６との間にもう１つの隔壁７８を形成して、これら両隔壁７６および７８間に断熱路を形成し、断熱路内の空気（熱）を冷却ファン７２へ導くようになっている。そして、これにより、両ランプ３２および６４が発する熱がＣＣＤカメラ５２へ伝わるのを確実に阻止して、ＣＣＤカメラ５２を保護するようになっている。

【００３４】図２に示すように、ケーシング２４の上面における両ランプ３２および６４の上方部位には、冷気吸引孔８０および８２が形成されており、これにより冷却ファン７０および７２による排熱効率を高めるようになっている。

【００３５】また、ケーシング２４の右側面には、格子退避ノブ６０の他に、電源スイッチ８４および通電表示ランプ８６が設けられており、その内面側には電子基板８８が設けられている。また、ケーシング２４の右側面からは、電源および信号用コード９０が延びており、その他端部において、電源用コネクタ９２、制御信号用コネクタ９４およびテレビ信号用コネクタ９６により、電源機器駆動部１４（図１参照）へ接続されるようになっている。

【００３６】ところで、モニタ１８上に現れるモアレ縞は測定ヘッド１２の観測光学系２８を介して取り込まれるので、被測定体２上において観測光学系２８の撮影レンズ４４に近い位置で形成されるモアレ縞と遠い位置で形成されるモアレ縞とでは、同じ格子線間隔のものであっても実際の奥行き寸法は互いに異なったものとなる。したがって被測定体２の正確な立体形状情報を得るためには、被測定体２上の各点の奥行き方向の位置に応じて像倍率の補正を行う必要がある。

【００３７】このため本実施形態においては、モアレ縞の観測の際、被測定体２の頂点と撮影レンズ４４との距離を測定するとともに、その測距データに基づいて被測定体２上の各点の像倍率補正および感度補正を行うようになっている。その際、被測定体２上の測距対象となる点は、像倍率補正および感度補正の基準となる点でもあるので、その奥行き方向（ｚ方向）と直交する平面（ｘ、ｙ平面）内における位置を正確に把握しておく必要がある。

【００３８】そこで本実施形態においては、被測定体２上の測距基準点として被測定体２の頂点を選出し、この頂点をモニタ１８上にフラグ表示するように構成されている。

【００３９】図５は、モアレ縞観測の際に行われる頂点選出、距離測定、像倍率補正および感度補正の手順を示す図である。

【００４０】まず、モアレ縞測定により頂点選出を行う（Ｓ１）。すなわち、フリンジスキャンを行いながらモアレ縞の画像を取り込んだ後、モアレ縞の縞解析を行い、内部設定値で高さ計算を行った後、被測定体２上の各点の３次元データ（ｘ，ｙ，ｚ）を算出し、この３次元データから頂点選出を行う。次に、選出された頂点をモニタ１８上にフラグ表示する（Ｓ２）。このフラグ表示された頂点位置をオペレータが確認してＯＫ入力を行うと（Ｓ３）、頂点と撮影レンズ４４との距離を自動測

定する（Ｓ４）。そして、その測距数値の自動入力を行った後（Ｓ５）、高さ計算式を演算し（Ｓ６）、その演算結果に基づいて被測定体２上の各点の像倍率補正および感度補正を行う（Ｓ７）。

【００４１】図６は、ステップＳ１の、モアレ縞測定による頂点選出の具体的手順を示す図である。

【００４２】まず、1/2πずつ位相のずれた被測定体２の画像を取り込む。その際、各取り込み画像の１点Ｐ（ｘ，ｙ）に着目し、その点の明るさＩをＩ１、Ｉ２、Ｉ３、Ｉ４と置くと、同図（ａ）に示すように表すことができる。

【００４３】これら位相の異なる４つの明るさデータから、この点の位相φを求めると、

$\phi = \tan^{-1}\{(I2-I4)/(I1-I3)\}$

となる。

【００４４】この位相φを各点について計算し、その位相計算結果をグラフにすると、同図（ｂ）に示すようになる。このグラフにおける最大値は２πであり、２π毎に途切れた曲線となる。

【００４５】この断続的な曲線に対して、該曲線を位相接続するアンラップ処理を行うと、同図（ｃ）に示すようになる。これにより、モアレ縞１縞当たりの高さをδ（δ＝２π）としたときの画像の各点の高さｚ（被測定体２の各点の相対的な奥行き寸法）が得られるので、被測定体２の頂点を見つけることができる。

【００４６】すなわち、

$z1(x1, y1) - z2(x2, y2) \geq 0$ (or>0)

であれば、Ｐ（ｘ１，ｙ１，ｚ１）を選び、

$z1(x1, y1) - z2(x2, y2) < 0$ (or≤ 0)

であれば、Ｐ（ｘ２，ｙ２，ｚ２）を選ぶという比較選択を測定領域全面にわたり行い、頂点Ｐ（Ｘ，Ｙ，Ｚ）を選出する。

【００４７】このとき、フレームメモリとＣＣＤのピクセルとが１対１で対応しているので、フレームメモリ中の座標とモニタ上の座標とは一致したものとなる。

【００４８】図７は、選出された頂点Ｐ（Ｘ，Ｙ，Ｚ）のｘｙ座標値Ｐ（Ｘ，Ｙ）をモニタ１８上にフラグ表示した図を示すものである。同図（ａ）は、モアレ縞解析結果を表示した画像（例えば等高線図）にフラグ表示した例を示し、同図（ｂ）は、ビデオスルー画像にフラグ表示した例を示すものである。これら２種類のモードでフラグ表示した図をモニタ１８上に切り換え表示するようにすれば、頂点Ｐ（Ｘ，Ｙ，Ｚ）が適切に選出されたことの目視確認を確実に行うことができる。

【００４９】図８は、頂点Ｐ（Ｘ，Ｙ，Ｚ）と撮影レンズ４４との距離を自動測定する方法を説明するための図である。

【００５０】この自動測定は、一般的なオートフォーカスの手法を用いて行われる。

【００５１】まず、自動測定に際し、予め観測用基準格子４６を退避位置へ退避させておく。

【００５２】そして、ＣＣＤカメラ５２のレンズ５２Ｌがホームポジションにあること、すなわち基準設定（１ｍ）がなされていることの確認を行った後、フラグ表示されたピクセルのビデオ信号の観察を行う。

【００５３】次に、レンズ５２Ｌをその光軸方向へ移動させ、山登り法によりピーク検出を行う。そして、このピーク検出が行われたときのレンズ５２Ｌの移動量εから、該移動量εに対応する物体側の点の奥行き方向の変位量ΔＬを算出する。レンズ５２Ｌがホームポジションにあるときの物体側の点と撮影レンズ４４の主点（物体側主点）Ｈとの距離Ｌから、変位量ΔＬを引いた値を算出することにより、被測定体２の頂点Ｐ（Ｘ，Ｙ，Ｚ）と撮影レンズ４４（の主点Ｈ）との距離Ｌ´（Ｌ´＝Ｌ－ΔＬ）が得られる。

【００５４】上記山登り法によるピーク検出は、図９に示す手順で行われる。

【００５５】すなわち、同図（ａ）に示すように、ＣＣＤカメラ５２のレンズ５２Ｌをその光軸方向へ移動させ、同図（ｂ）に示すように、各移動位置における画像を取り込む。その際、同図（ｃ）に示すように、頂点Ｐ（Ｘ，Ｙ，Ｚ）に対応するピクセルの出力をグラフにプロットし、その出力が最大になるときのレンズ位置（すなわち合焦点位置）をピーク検出位置として決定する。

【００５６】このとき、図１０（ａ）に示すように、ピーク検出位置での頂点Ｐ（Ｘ，Ｙ，Ｚ）を含むｘ軸方向およびｙ軸方向の断面をとり、図１０（ｂ）、（ｃ）に示すように、フラグ表示されたピクセルを含むｘ軸方向およびｙ軸方向の各ピクセルの出力をグラフにプロットすれば、上記ピーク検出位置において頂点Ｐ（Ｘ，Ｙ，Ｚ）がピーク値になっていることの検証を行うことができる。

【００５７】なお、上記物体側の点の変位量ΔＬの算出には、次の関係式が用いられる。

【００５８】すなわち、図８において、物体側の点がΔＬ変位したとき撮影レンズ４４により形成される結像点の変位量Δｂは、撮影レンズ４４の焦点距離をｆとすると、

$\Delta b = (f/(f-L))^2 \Delta L$

となる。そして、これに伴うＣＣＤカメラ５２のレンズ５２Ｌの移動量εは、レンズ５２Ｌの焦点距離をｆ´とすると、

$\varepsilon = (f'/(f'-L))^2 \Delta b$

となる。したがって、これら２式より、

$\Delta L = \{(f'-L)(f-L)/f'f\}^2 \varepsilon$

が得られる。

【００５９】本実施形態においては、頂点Ｐ（Ｘ，Ｙ，Ｚ）と撮影レンズ４４との距離の測定を自動測定により

行う場合について説明したが、メジャー等を用いて手作業により測定を行うようにしてもよい。この場合、モニタ１８上における頂点Ｐ（Ｘ，Ｙ，Ｚ）のフラグ表示が、モアレ縞解析結果を表示した画像とビデオスルー画像との双方において行われるので、頂点Ｐ（Ｘ，Ｙ，Ｚ）が適切に選出されたことの目視確認を確実に行うことができる。

【００６０】

【発明の効果】本発明に係るモアレ装置は、投影格子をフリンジスキャンさせながらモアレ縞観測を行い、その結果から被測定体の３次元データを算出し、この３次元データから被測定体上における測距基準点を選出し、この測距基準点をモアレ縞観測用のモニタ上にフラグ表示するように構成されているので、フラグ表示された点を目印にして被測定体と観測光学系の撮影レンズとの距離測定を行うことができ、その測定精度を高めることができる。そして、これにより像倍率補正および感度補正の精度を高めることができるので、被測定体の正確な立体形状情報を得ることができる。

【００６１】この場合において、上記基準点を被測定体の頂点とすれば、像倍率補正および感度補正の処理を容易化することができる。

【図面の簡単な説明】

【図１】本発明の一実施形態に係るモアレ装置の全体構成を示す斜視図

【図２】図１に示すモアレ装置の測定ヘッドの外観を示す斜視図

【図３】図1に示す測定ヘッドの内部構造を示す斜視図

【図４】図1に示す測定ヘッドの機能を説明する平面図

【図５】図1に示すモアレ装置によるモアレ縞観測の際に行われる頂点選出、距離測定、像倍率補正および感度補正の手順を示すフローチャート

【図６】モアレ縞測定による頂点選出の具体的手順を説明するための概略図

【図７】選出された頂点をモニタ上にフラグ表示した状態を示す概略図

【図８】頂点と観測光学系の撮影レンズとの距離を自動測定する方法を説明するための概略図

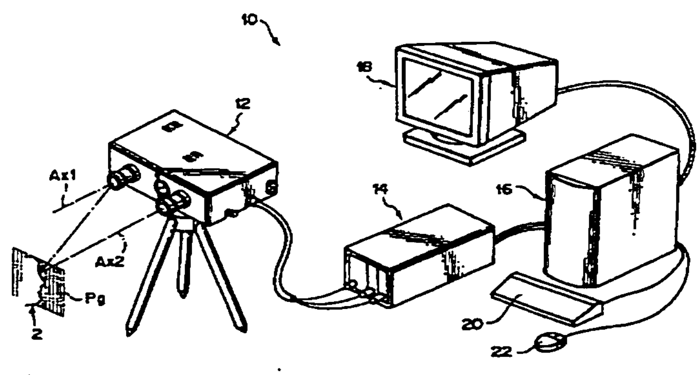
【図９】山登り法によるピーク検出の手順を示す概略図

【図１０】ピーク検出位置の検証方法を示す概略図

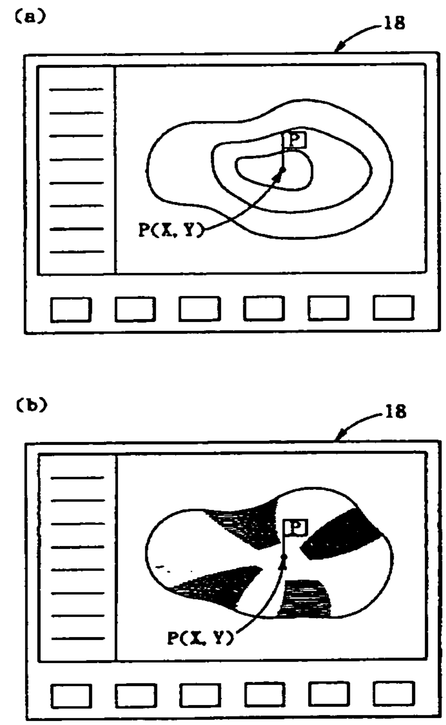
【符号の説明】

２　被測定体
１０　３次元イメージスキャナ（モアレ装置）
１２　測定ヘッド
１４　電源機器駆動部
１６　制御部
１８　モニタ
２４　ケーシング
２６　投影光学系
２８　観測光学系
３０　被測定体照明系
３２　投影用ランプ
３６　コンデンサレンズ
３８　格子照明系
４０　投影格子
４２　投影レンズ
４４　撮影レンズ
４６　観測用基準格子
４８　フィールドレンズ
５０　折り返しミラー
５２　ＣＣＤカメラ
５２Ｌ　レンズ
５４　テレビ光学系
５６　格子送り機構
５８　格子退避機構
６２　リミットスイッチ
Ａｘ１、Ａｘ２　光軸
Ｐｇ　仮想基準格子面
Ｐ（Ｘ，Ｙ，Ｚ）　頂点（測距基準点）

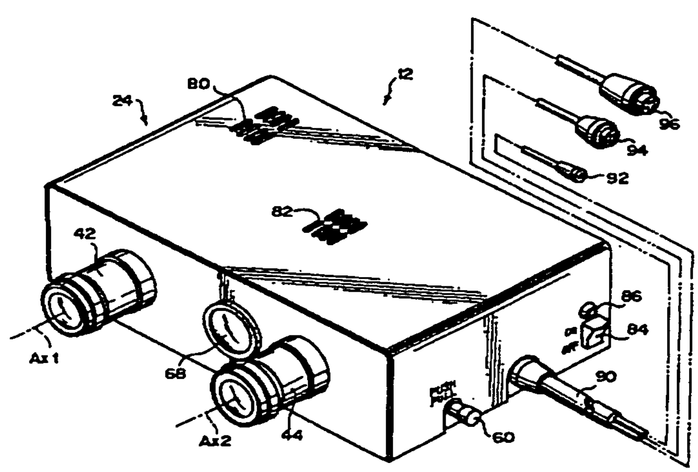
【図１】


10
18
12
Ax1
Ax2
14
16
Pg
2
20
22

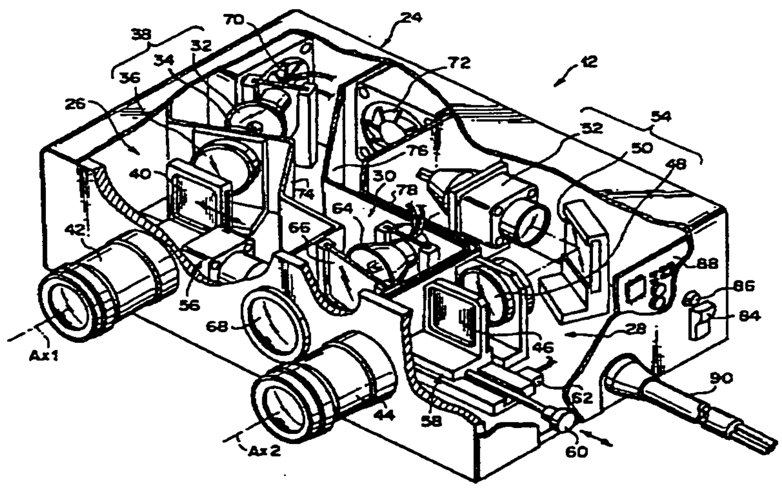
【図７】


(a)
18
P
P(X, Y)
(b)
18
P
P(X, Y)

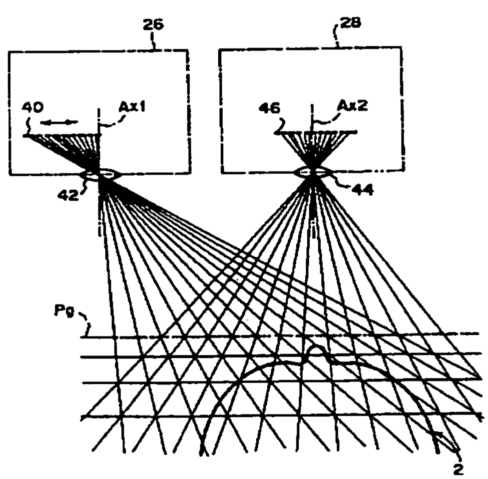
【図２】


80
24
12
96
94
92
82
42
86
84
Ax1
68
90
PUSH PULL
44
60
Ax2

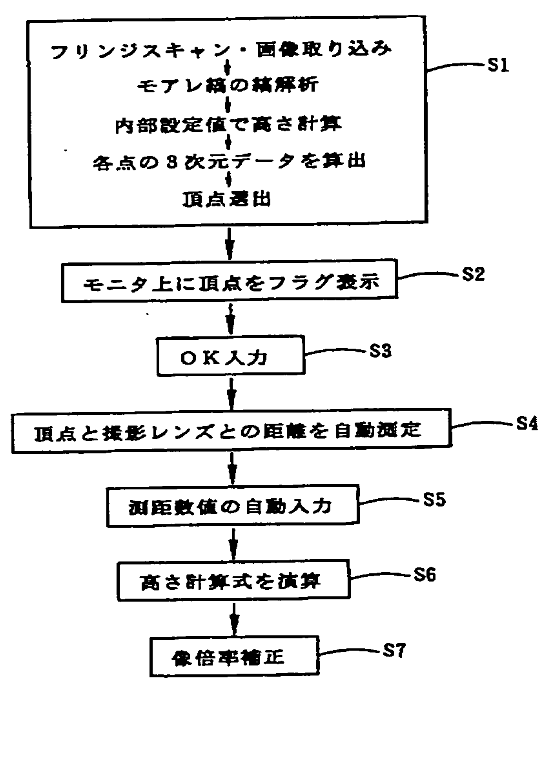
【図３】


12
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
84
86
88
90
Ax1
Ax2

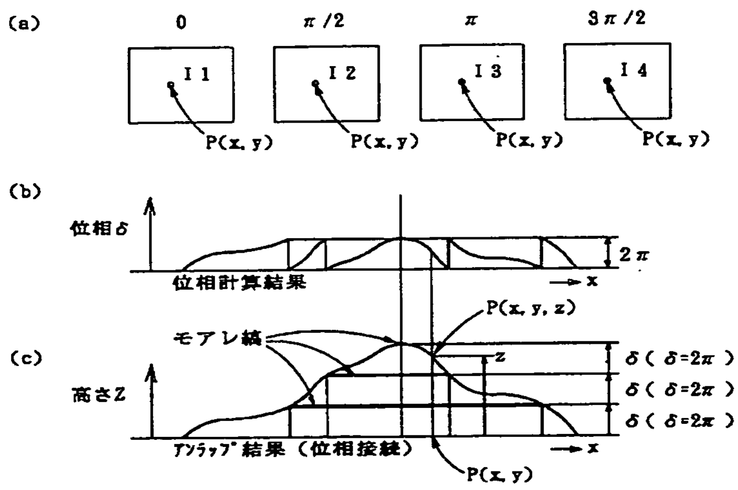
【図４】


26
28
40
Ax1
46
Ax2
42
44
Pg
2

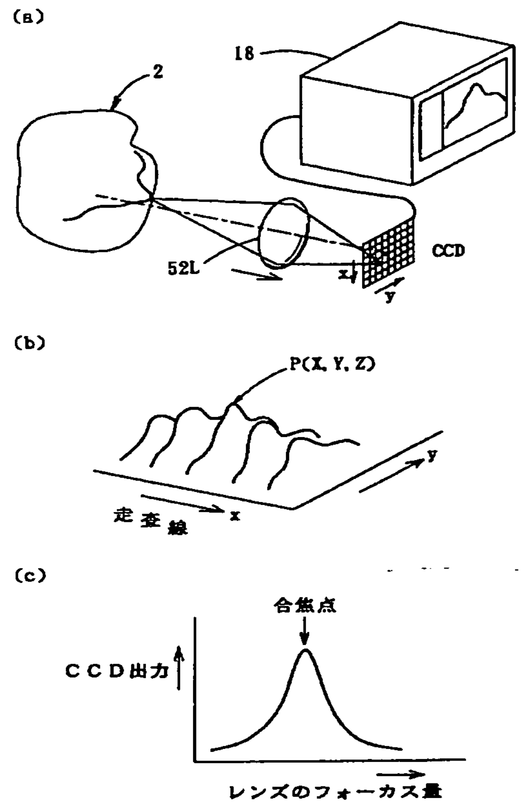
【図５】


フリンジスキャン・画像取り込み
モアレ縞の縞解析
内部設定値で高さ計算
各点の３次元データを算出
頂点選出
S1
モニタ上に頂点をフラグ表示
S2
ＯＫ入力
S3
頂点と撮影レンズとの距離を自動測定
S4
測距数値の自動入力
S5
高さ計算式を演算
S6
像倍率補正
S7

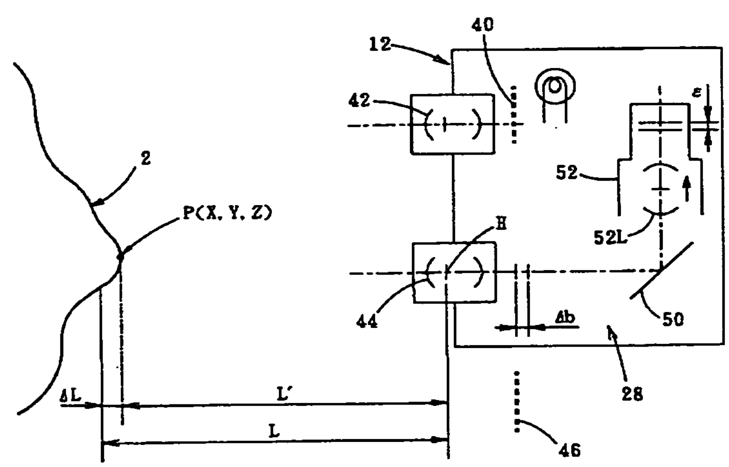
【図6】


(a)
0
π/2
π
3π/2
I 1
I 2
I 3
I 4
P(x, y)
(b)
位相δ
2π
位相計算結果
x
(c)
P(x, y, z)
モアレ縞
z
δ (δ=2π)
高さZ
アンラップ結果（位相接続）
P(x, y)

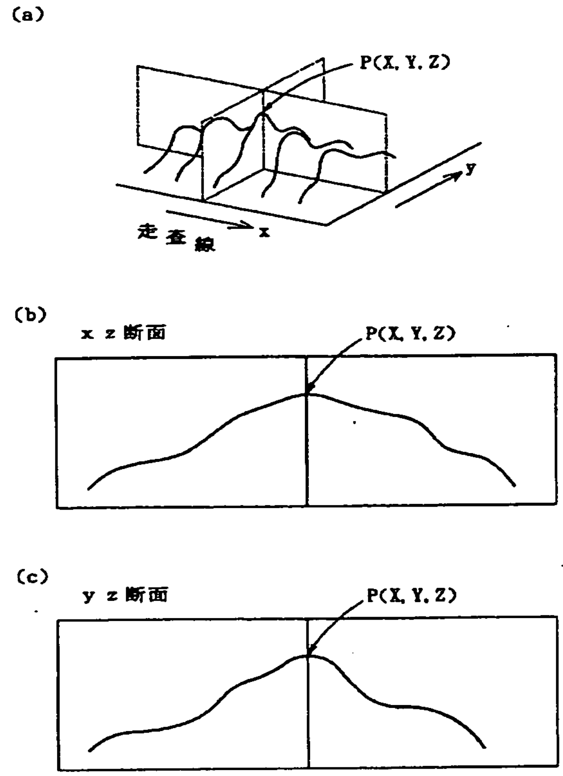
【図9】


(a)
18
2
52L
CCD
x
y
(b)
P(X, Y, Z)
y
走査線
x
(c)
合焦点
CCD出力
レンズのフォーカス量

【図8】


12
40
42
2
P(X, Y, Z)
ε
52
52L
H
44
Δb
50
28
ΔL
L'
L
46

【図１０】



フロントページの続き

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